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RF BROADCAST AND CABLE TELEVISION DISTRIBUTION SYSTEM AND TWO-WAY RF COMMUNICATION

Abstract:

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(A1) Systems for communicating video and other information over twisted pair wires that may be actively conducting telephone or data information. An audio/video transmission system for facilitating transmission of video, hi-fi audio, digital, and control signals (such as infrared remote control signals) between different locations in a residence (411a) using existing and active telephone wiring. Simultaneous transmission of signals of each type over active telephone lines is achieved without interference with telephone communications or with the other signal types. Transmission succeeds without requiring special treatment of the video signals beyond RF conversion, despite signal attenuation inherent in transmission over the telephone line media. The fidelity of audio reproduction at the receiving locations is sufficiently high to support the transmission of signals from digital devices without significant loss of audio quality. Multiple video sources and high fidelity audio sources may be tied into the system and selected as desired. Remote control signals generated in one room may be utilized to control video and audio sources in another room without requiring a clear line of sight between the remote control device (492a) and the receiver (419a).

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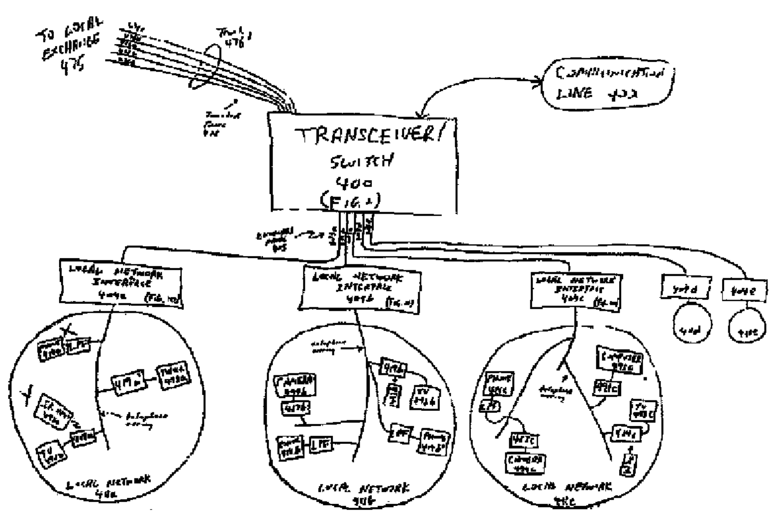

(57) Abstract

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RF BROADCAST AND CABLE TELEVISION DISTRIBUTION SYSTEM AND TWO-WAY RF COMMUNICATION

BACKGROUND OF THE INVENTION

The motivation for the transmission of hi-fi audio signals is an outgrowth of the need to transmit the signals from each entertainment source to every corresponding receiver in a building. (Hereinafter, the term "residence" will be used to generally refer to any building that contains telephone wiring, such as an ordinary single-family home, an apartment, or a commercial building.) There is a need, for example, to transmit the signals from video entertainment sources, i.e. video cassette recorders (VCRs), cable converters, and satellite signal receivers, to every video receiver, i.e., each television. A similar need for communication between audio sources and receivers also exists. In audio systems, the sources include cassette decks, record players, compact disc (CD) players, FM tuners, and turntables. The receivers are the loudspeakers and earphones while amplifiers can be classified as part of either category.

In the classical situation, source and receiver are located close to each other in the same room. To enjoy music or video, however, one does not need to be in close proximity to (or even in the same room as) the signal source. Rather, one only needs to be within visual range of the video receiver or audio range of the audio receiver (so as to be able to see or hear the desired signals) and have an ability to control the sources. Thus, an ability to communicate audio, video, and control signals between rooms will allow one to enjoy music and video using only speakers and a television. While U.S. Patent No. 5,010,399 provided a solution to the problem of transmission of video and control signals, no inexpensive solution to the transmission of hi-fi audio, much less the simultaneous transmission of all three signals, has been developed to

date.

Hi-fi audio signals can be transmitted across a residence using radio waves as well as by transmission across a wire or other conductive path. Broadcasting signals, however, allows for the possibility of unintended reception outside the residence, and also allows for the possibility of interference from external sources broadcasting at the same frequency. Government regulations covering the broadcast of these signals also present significant obstacles.

Common conductive paths within a residence include power wiring (i.e., wiring that carries 120 VAC, 60 Hz household power), telephone wiring, and coaxial cable. Coaxial cable does not offer a comprehensive solution because it is not available in most residences. It is also bulky, stiff, and unwieldy. Moreover, the signal splitters commonly used in coaxial cabling block transmission between the two downstream ports (i.e., the output ports of the splitters), preventing communication across some of the conductive paths.

Transmission across power wiring is difficult because electrical appliances can impart significant noise onto the wiring network, and because the conductive path is often broken across a fuse box or circuit breaker. Although some systems use power wiring as a conductive path for hi-fi transmission, the systems are relatively expensive, owing to the need for overcoming extremely high noise on the power lines. Even using expensive circuitry, line noise may be so high that it cannot be suppressed in many situations. Moreover, such systems cannot reliably transmit between the differently phased conductors on a 120V residential system, because the conductive paths used by the two phases may only connect far from the residence. Finally, video signals typically cannot be transmitted over power lines with any reasonable degree of quality, so

simultaneous transmission of television signals and audio is not possible.

Telephone wiring also presents significant difficulties to the transmission of audio signals. Two obvious difficulties are the requirement of avoiding interference with telephone communications and conforming with all regulations that govern devices that connect to the public telephone network. Other difficulties are presented by the transmission properties of telephone wiring. These include the attenuation of the telephone wiring itself, the attenuation caused by junctions in the wiring and connected telephones that drain RF energy from the network, and switching devices that break conductive paths.

Devices are available that overcome some of these difficulties to achieve transmission of intelligible audio. Radio Shack™, for example, manufactures a telephone that, when used with an identical cooperating telephone, provides intercom communication at frequencies above the voiceband. These phones work over ordinary telephone lines used in residences. In addition to its limitation as a monaural rather than a stereo signal, however, the sound quality produced by this telephone does not approach that of most hi-fi systems. That is, such a system cannot transmit high fidelity sounds between the telephones in a manner that would maintain the high fidelity at the receiving telephone. The same is true for other systems known to transmit audio information across active telephone wiring. None of these systems, moreover, simultaneously transmit video signals or control signals from infrared transmitters.

While transmission of digital signals within a residence is not currently an urgent need, that situation is expected to change rapidly over the next several years. There are currently several systems, designed to be used in

office environments, that perform digital transmission over active telephone wires. The catalog of the Black Box Corporation, for example, includes several transmit/receive pairs that perform this function. These devices connect to a digital device to derive a digital datastream that adheres to a particular format, e.g., the IEEE RS-232 standard. This information is converted to a time varying voltage at frequencies above the voiceband of telephones. These signals are then fed to an active telephone wire (i.e., a wire used for voiceband communication) that connects directly from point A to point B without any devices connected in the middle (a so-called "point-to-point" connection). This line typically connects between a telephone and a PBX device. At the end of the line, a receiving device connects to detect the high frequency voltage variations, and convert them back to the original digital datastream.

Because this system transmits data over a point-to-point telephone lines that do not include splits, branches, or telephone devices that are connected in the middle, they may not work over networks with arbitrary topologies and telephone devices connected at random points, features found in the internal telephone wiring of nearly all residences.

Distribution of Cable TV signals throughout a residences is an important communication link that also has considerable room for improvement. Despite many technical advances in video transmission that have accompanied the rapid growth of cable TV in recent years, coaxial cabling typically must be installed before the televisions of a residence can receive cable signals. Because most residences did not have this wiring installed at the time of construction, provision of cable TV usually incurs an installation cost. Furthermore, unless this installation is done carefully, which is expensive, damage

to the trim of the residence (both interior and exterior) is likely. Finally, coaxial cabling is stiff and unwieldy, making it difficult to keep out of sight, and reducing the mobility of connected video equipment.

A second category of problems arises when two televisions in a residence are to be provided with cable signals. In this case, a converter box for each television is required unless the televisions are "cable-ready" and descrambling is not needed. Each converter box must include descrambling circuitry, an infrared (IR) detection and interpretation capability (if IR remote control devices are to be used), an ability to detect control signals sent from the local cable company that include the unique address of the converter box, and a power supply, among other things. This can be expensive.

The video transmitters, receivers, and transceivers described in U.S. Patent No. 5,010,399 feed RF signals onto the active telephone wiring and recover signals from the same medium. In particular, these devices are designed to communicate video and control signals at RF frequencies across the telephone wiring. One focus of this application is to adapt these devices and technologies to provide a system whereby cable signals can be supplied less expensively.

The provision of cable TV to an apartment building is yet another part of the cable TV distribution system that embodies significant problems. If coaxial cabling is not included at the time of construction, a coaxial cable leading through the entire building must be installed, and a branch must connect between each of the individual apartment units to a point on this cable. This is obviously an expensive procedure, even if easily accessible cabling conduits exist. Furthermore, each branch provides service at only one location within the unit it connects. Extra branches must be installed to provide cable TV

service at other locations in the unit.

Providing a group of TV signals to various rooms in an office building currently requires a similar amount of coaxial cable installation. The demand for economical video distribution within office buildings is increasing, moreover, because of the increased popularity of video teleconferencing.

The method of distributing cable TV signals commonly used in the U.S. can be called a "one-way branched" system because signals transmitted at the head-end (i.e., at the root or entrance point to the network) spread across to each of the various subscribers by continually splitting into multiple downstream branches. Due to an increase in the popularity of video programming, however, demand for a new system has emerged. Under the new system, sometimes called "video on demand," a subscriber can request a specific program from a library of programs stored at a central location on, for example, video tapes. The signal from this program is subsequently sent to the subscriber from the "head end" of the system. No other viewers can receive the same signal unless they make a similar request.

One method for providing video on demand is to install a high-capacity fiber optic transmission line from the library through a series of residential or commercial neighborhoods. At each neighborhood, all signals targeted for the local residences or businesses (hereinafter, the term "residence" is used to mean both types of buildings unless otherwise stated) are encoded (i.e. scrambled) and then "handed off" at different channels onto the coaxial cable branch that feeds those residences. Thus, each neighborhood has its own individual headend at the point of handoff.

To prevent all residences from receiving each of the signals handed off to their neighborhood, a control signal is sent over the fiber optic transmission line that

includes the "address" of a converter box in the house of the subscriber who requests a particular signal. This control signal provides descrambling instructions that, because of the addressing, only the targeted converter box will recognize. Under this system, each subscriber receives all signals targeted for his or her neighborhood, but only the program (i.e., the specific video signal) actually requested by a subscriber becomes available to him or her in unscrambled form.

The concept of "video on demand" can be considered to be part of a broader communication concept. The broader concept is the widening of communication paths to the ordinary subscribers on the switched public communication network. This would enable subscribers to communicate video signals and other relatively wide bandwidth signals in the same way that they currently communicate voice signals.

The transmission medium that is best suited to provide wider communication paths is fiber optic cables. Indeed, many of the public telephone companies have converted most of their main communication trunks to fiber optics, and have upgraded their switching equipment to handle these signals and their attendant increase in data rates.

To bring the wider capacity to an individual site, however, requires one to install a new fiber optic branch from the main fiber optic trunk to each local network (i.e. a house, apartment unit, or a room in an office building), and to switch signals from the trunk onto the branches. Furthermore, conversion from light to electrical signals must take place at the point where the branch reaches the targeted residence. (Conversion is necessary because the communication devices currently found in typical residences and offices respond to electrical signals.) Finally, the electrical signals must be distributed through the house.

INTRODUCTION

This invention relates to transmitting various signals at radio frequencies across networks of active internal telephone links (that is, telephone wiring which carries telephonic signals within a commercial or residential building) with arbitrary topologies. The disclosures presented herein are partly an outgrowth of ideas and technology disclosed in U. S. Patent No. 5,010,399 which describes methods for transmitting video signals (i.e., visual and sound signals for televisions and the like) and control signals issued by infra-red transmitters across telephone wiring and is incorporated herein by reference.

More specifically, one aspect of this invention represents refinements of the transmission techniques disclosed in the parent application to achieve improved results, particularly regarding transmission of audio signals and digital signals across active telephone wiring. These improvements embody methods for communicating the audio and digital signals across active telephone networks that, in addition to carrying voice information from telephone devices, are also in use as a medium for communication of video and control information. The improvements include devices that simultaneously transmit and receive several RF (radio frequency) signals of varying types through a single connection to a network of telephone wiring. The improvements also include a method for cancelling interference caused by certain telephone devices, and various techniques to increase the total number of channels and the distances over which video signals can transmit.

Another closely related aspect of the invention relates to a system for distribution of cable TV signals over networks of internal telephone wiring. The invention discloses systems for coordinating various transmission and

reception functions to provide several improvements in video communication over the active telephone wiring of a residence. In particular, a method of distributing multiple cable TV signals without installing new wires (such as coaxial cable dedicated to the cable TV signals) is disclosed. Technology to provide video graphics to televisions and other video devices connected to the internal telephone network is also disclosed.

Yet another closely related aspect of the invention relates to a system for simultaneous two-way communication of video signals and other signals between multiple networks of telephone wiring whose twisted pairs converge together into a single bundle, wiring block, or other common point of access, and a high capacity communication line located at that point of access. Each network includes a set of interconnected, active telephone wires (i.e., a group of wires that create a conductive path for telephonic signals) internal to a house, an apartment unit, or a room in a commercial building. (Such wiring internal to houses, apartment units, or rooms in commercial buildings shall be referred to herein as "local networks.") In the case of houses, the point of common access can be a telephone pole. In the case of apartment buildings, the point of access can be the "wiring closets" found in those buildings. In the case of commercial buildings, the point of access can be the electronic PBX, or "private branch exchange" common to those types of buildings. The high capacity line can be a coaxial cable or an optical fiber. In addition to communication between each network and the high capacity line, communication from one network to another is also provided. The distribution system works just as well when the point of convergence is the center of a computer communications network with a "star" topology, and the wires are the twisted pair wires connecting each individual computer to this center.

SUMMARY OF THE INVENTION

This invention refines the methods described in U.S. Patent No. 5,010,399 to provide transmission of a broader range of video signals over even longer path lengths with still less susceptibility to interference or distortion due to transmission-induced noise. Moreover, the invention allows high-fidelity audio (such as stereo) signals to be derived from a sound system and transmitted across networks of active telephone wiring without significant loss in the signal properties that determine sound quality (i.e., without any substantial degradation in the fidelity of the audio signals). In addition, the invention enables video, audio, and control signals for the video and audio sources to be simultaneously communicated at radio frequencies over active networks of telephone wiring without interfering with each other or with the telephone voice signals or the operation of telephones connected to the wiring. This allows the user to achieve multiple types of communication (video, audio, and control) with only two discrete electronic devices (i.e., the transmitter and receiver pair provided by the invention and discussed below). It also allows the user to export an entire audio/video entertainment system to a second location in a residence by providing that location with a television and speakers.

Accordingly, one general aspect of the invention is a system for communicating video signals between a source and a destination thereof and that includes a transmitter coupled between the source and a first location on a telephone link that carries voice signals from at least one telephone connected to the link (i.e., an active telephone link), and a receiver coupled between a second location on the telephone link and the destination. The transmitter frequency modulates the video signals from the source in a selected frequency band that exceeds frequencies of the voice signals, and couples the frequency modulated signals

onto the telephone link. The receiver recovers the frequency modulated signals from the telephone link, demodulates the frequency modulated signals to reproduce the video signals, and applies the reproduced video signals to the destination.

Because frequency modulation (FM) is used, the signal sent over the telephone lines has high immunity to noise and other distortion that are caused by, e.g., the length of the telephone link and splits and other junctions that are typically present on active residential telephone lines. Longer telephone lines between the source (such as a VCR) and the destination (e.g., a television) can be used without degrading television picture and sound quality.

Preferred embodiments include the following features.

The transmitter and receiver each include circuitry (such as filters) for impeding the voice signals on the telephone link from being coupled to the modulation and demodulation circuitry in the transmitter and receiver. This prevents the modulation and demodulation circuitry from "loading down" the voice signals. Likewise, the transmitter and receiver include filters, coupled between the telephone and the telephone link, for impeding the frequency modulated signals from being coupled to the telephone. As a result, the modulated video signals are transmitted over the telephone link with high immunity from telephone loading effects.

A second telephone can be coupled to the telephone link at first location, the second location, or elsewhere on the link. Filtering is used avoid mutual interference between the voice signals and the modulated video signals.

In another general aspect of the invention, the transmitter and receiver communicate audio signals that have a predetermined fidelity level between a source (such as a high fidelity transmitter) and a destination via the

active telephone link. The transmitter converts the audio signals to a frequency band that exceeds frequencies of the voice signals in a manner that substantially preserves the predetermined fidelity level and couples the converted signals onto the telephone link. The receiver recovers the converted signals from the telephone link, reconverts them from the frequency band to audio signals in a manner that substantially preserves the predetermined fidelity level, and applies the audio signals to the destination (such as an audio receiver or speakers).

Preferred embodiments include the following features.

The audio signals are converted to the frequency band by modulation (such as FM or AM). Similarly, demodulation is used at the receiver to reproduce the audio signals from the modulated signals received from the telephone link. The source produces the audio signals in a pair of channels and the destination is adapted to receive the audio signals in a like pair of channels (so-called left and right channels). Modulation and demodulation are performed separately (using different modulation frequencies within the band) for each channel. The use of different frequencies for the two channels avoids the channels interfering with each other on the telephone link. The receiver also includes circuitry for controlling the amplitude of the recovered signals in each of the channels.

In another general aspect of the invention, the transmitter and receiver are constructed to exchange several different types of signals, for example, video signals, audio signals, and control signals, over the active telephone link. The transmitter and receiver can exchange all of these signals or any subset thereof.

The transmitter converts the video signals and the audio signals to a different frequency bands that exceed

frequencies of said voice signals, and couples the converted video signals and audio signals onto the telephone link. At the receiver, the converted video signals and converted audio signals are recovered from the link, and the video signals and the audio signals are reproduced therefrom, and applied to their respective destination. The receiver also receives the control signals (which are, e.g., radiated from a source such as a hand-held control unit) converts the control signals to yet another frequency band that exceeds frequencies of the voice signals, and couples the converted control signals onto said telephone link for transmission to said transmitter. The transmitter, in turn, recovers the converted control signals from the telephone link, reproduces the original control signals (such as in the form of infrared energy) therefrom, and applies the reproduced control signals to either or both of the video source or the audio source.

Preferred embodiments include the following features.

The transmitter and the receiver each use bandpass filtering to avoid mutual interference between the video signals, the audio signals, the control signals, and the voice signals.

In yet another general aspect of the invention, a television signal that includes an amplitude modulated video component and an accompanying frequency modulated audio component and that is sent by a source thereof over a communication link, possibly with the introduction of noise on the signal, is recovered and applied to a television receiver in a way that substantially reduces noise level. Variations in said amplitude of the audio component of said recovered television signal are measured as an indication of the level of the noise in the video component, and the measured variations are used to reduce

the level of noise in the recovered television signal.

This aspect of the invention takes advantage of the fact that the audio component is usually close in frequency to the accompanying video component, and therefore is likely to be similarly affected by noise. Moreover, because the audio component is frequency (rather than amplitude) modulated, the amplitude variations are treated as noise with a high degree of confidence.

Preferred embodiments include the following features.

The audio component is separated (such as by bandpass filtering) from the video component. This is possible because the audio component typically has a carrier frequency that is outside of a frequency band that includes the video component. The amplitude of the audio component is averaged over a selected time period. This average provides an accurate indication of the noise level.

The transmitters, receivers, and transceivers described in U.S. Patent No. 5,010,399 are designed to work on any network of telephone wiring where an uninterrupted conductive path exists between any two points. The network may or may not be conducting telephone signals while these components are transmitting RF signals. Loops are allowed. Nearly all residential networks fit this description. The only common exceptions are residences where all jacks are directly connected to a central electronic switch/processor. In U.S. Patent Application 5,010,399, an adapter is described that provides a bypass around this switch, allowing transmission of RF signals to all points of the wiring. The adapter is equally applicable for use with the present invention. The transmitters, receivers, and transceivers use the telephone wiring as a broadcast medium, functioning like wireless communication devices, except that the telephone wiring is the medium rather than the airwaves. Because cable TV signals commonly adhere to

commercial broadcast standards, such as NTSC, PAL, or SECAM, the video transmitters and receivers of U.S. Patent No. 5,010,399 can be used to distribute individual cable TV channels as well as the video signals from VCRs, video cameras, etc., over active telephone wiring of the residence. In the most straightforward implementation of the systems described in the U.S. Patent No. 5,010,399, a cable converter box connects to one of the video transmitters, and signals tuned by the converter box are fed to this transmitter. The transmitter processes these signals and feeds them to the telephone wiring. This creates a link with the televisions (and other video receivers such as VCRs) that are connected to video receivers on the telephone wiring network. At the same time, remote control units (such as a hand held device that transmits infrared (IR) control signals) usable with the converter box can control the converter box from remote locations through the infrared communication system of the internal telephone network. In this system, the control signals are converted to electrical signals by a video receiver connected to the network and located in the vicinity of the remote control unit (such as in the same room as the user), and the electrical signals are sent from that video receiver over the telephone network to the video transmitter associated with the converter box. That video transmitter recreates the infrared pattern and broadcasts it through the air for reception by the IR window of the converter box.

One important improvement that this invention provides is to unify the cable converter box and the video transmitter onto the same circuit board and within the same housing, and to provide the cable converter box with the capability of tuning and selecting between several signals at once. Such a converter box yields a number of advantages in providing cable TV to a residence. For

example, the cable converter box is located on or near an outer wall of the residence and the cable TV company only need bring a cable to that location and connect it to the box -- there is no need to carry the coaxial cable further into the residence. The converter box also connects to the telephone wiring from the public telephone network and feeds both the telephone signals and the cable TV signals onto the internal telephone network of the house over ordinary telephone wires (i.e., a four conductor cable that typically includes wires sheathed in red, green, black, and yellow insulation -- the so called "red-green" and "black-yellow" wire pairs). The need to install any coaxial cabling in the house is eliminated.

The methods described in U.S. Patent Application 5,010,399 transmit many signals (typically more than 10, depending on the length and topology of the wiring over the telephone wiring) at once. Because cable TV companies typically provide at least forty different signals on their cables, one way to allow complete freedom in channel selection is to perform the channel selection at the distribution site, where the coaxial cable connects to the cable converter box. In addition, the users should be able to signal a channel change from the location of the connected television, a location often removed from the site of the cable converter. This invention provides these capabilities.

Another aspect of the invention also overcomes difficulties that arise when a single cable converter transmits multiple signals over multiple frequency bands and a user wishes to change the channel that is sent over one of those bands. The problem is that the user must have a way of indicating which of the bands is to be used to transmit a different signal. Assume, for example, that the communication system tunes in cable signal A and sends it to all televisions on the internal telephone network at VHF

channel 8. Further assume that the system tunes in cable signal B and provides it so that it is displayed on televisions at VHF channel 10. A viewer watching signal A on VHF 8 can use the remote control unit in the manner discussed above to key in a request for channel C, but that does not in itself indicate that the newly-selected channel C should appear on VHF channel 8. The RF/video processor of this invention gives the user the ability to specify that the newly-selected channel is to appear on the correct television channel (i.e., VHF channel 8).

Another difficulty that arises when multiple signals are sent -- and that is overcome by this invention -- is the coordination of remote control units. A consumer at a site in the residence at which a television is connected to the telephone network may want to control many different devices with a single control unit. In addition to the television itself, these will often include a cable converter and a VCR that are located elsewhere in the residence. Such a problem can be solved by universal remote controllers, which include or can learn the commands sets of other controllers. Provision of such controllers, in addition to the controller already provided with a television, is an extra expense. Means to control multiple devices with an ordinary controller can reduce this expense, particularly if there are several televisions connected at the remote locations.

To solve these problems the unified cable converter box of this invention includes an interface that connects to the network of internal, active telephone wiring and an incoming coaxial cable (e.g., from a cable television hook-up that originates from outside the residence) that provides video signals. The invention also provides improvements in the video receivers and transmitters that are connected to the internal telephone network and serve as interfaces between the network and various video sources

(e.g., VCRs) and receivers (e.g., televisions). The interface includes an RF/video processor having circuitry that coordinates all of these units to provide the following results:

1) Under control of users in the residence, the RF/video processor selects between multiple cable signals and transmits each of the selected cable signals across the internal telephone wiring.

2) Video receivers connected to the telephone wiring embody improvements over video receivers described in U.S. Patent No. 5,010,399. These improvements will allow the receivers to supply connected televisions with multiple (such as five or more) video signals (selected from the incoming cable TV signals and also from signals provided by other sources on the network, such as VCRs and cameras) within, e.g., adjacent high-VHF or UHF channels. The video receivers also provide the received signals at non-adjacent channels. This is useful when more than five signals are being transmitted across the wiring.

3) A user can communicate with the RF/video processor via touch tones (i.e., DTMF signals) delivered from any telephone connected to the internal network, or via control signals from any infrared transmitter (located near video receiver on the network).

4) The RF/video processor also includes circuitry that allows any infrared transmitter to exercise complete control over all infrared responsive devices connected to the internal telephone network.

5) The RF/video processor further includes microprocessor (e.g., graphics processors) that can, among other functions, display alphanumerics and other images on the connected televisions, providing textual and graphical communication with viewers.

The RF/video processor is designed to work on any network of telephone wiring where an uninterrupted conductive path exists between any two points. Loops are allowed. Nearly all residential networks fit this description. The only common exceptions are residences where all jacks are directly connected to a central electronic switch, but (as discussed above) the adapter

described in U.S. Patent No. 5,010,399 can be used with this invention to allow communication across those networks.

The RF/video processor distributes several different cable TV signals simultaneously across the active residential internal telephone wiring. As a result, the invention serves the large demand (at least in the U.S.) for the ability to watch different cable channels on different televisions (e.g., in various rooms of the residence) at the same time, and also provides the highly desirable capability of allowing a user to view one cable channel while recording a second.

Thus, in accordance with one aspect of the invention, a system for video signal communication between a source of the video signal located outside of a unit and a destination of the video signal within the unit includes an interface coupled to the source and to an internal telephone link that carries voice signals from at least one telephone connected to the link. The interface receives the video signal from the source, and transmits the received video signal onto the telephone link within a frequency range selected to be different from frequencies at which the voice signals are carried on the telephone link. The video signal is then coupled by the link to a connected receiver, which is adapted to recover the video signal from the link and apply it to the destination.

Preferred embodiments include one or more of the following features.

The unit is a residence such as a house or apartment, or a commercial building such as an office complex. Hereinafter, the term "residence" will be used to include all of these types of units. The source is a cable (such as a coaxial or fibre optic cable) that is linked to the residence and carries a plurality of video signals, and the destination is a television.

The interface selects at least one of the video signals in response to control information from a user of television and transmits the selected video signal onto the telephone link for recovery by the receiver and application to the television. If the television is adapted to receive the selected video signal in a predetermined frequency band (e.g., a given VHF channel), the interface transmits the selected video signal onto the telephone link at a band within the selected frequency range that allows the receiver to apply the recovered video signal to the television in that predetermined frequency band.

Multiple televisions each of which is connected to the telephone link by a receiver can also be used. In this case, the interface responds to control information from users of the televisions by selecting one or more of the video signals and transmitting them onto the telephone link at different frequencies within the selected frequency range for recovery by the receivers and application to the respective televisions.

The interface is also connected to a telephone line that is connected to said telephone link and extends outside of the residence. The interface includes circuitry for passing the voice signals between the telephone link and the telephone line while preventing the video signal from being applied to said telephone line. Bandpass filtering can be employed for this purpose. The voice signals are carried on the telephone link at voiceband frequencies, and the selected frequency range exceeds the voiceband frequencies.

In another aspect of the invention, the interface serves to retransmit video signals that are transmitted from a source at one location on the telephone link to a destination located elsewhere on the telephone link. More specifically, the interface receives a video signal transmitted by the source over the telephone link in a

first frequency range that is different from frequencies at which voice signals are carried on said telephone link, and then retransmits that video signal onto the telephone link in a second frequency range that differs from both the first frequency range and the frequencies of the voice signals. The retransmitted video signal is coupled via the telephone link to a receiver that recovers the video signal and applies it to the destination.

Preferred embodiments include the following features.

The destination is a television located together with the source within a residence. The interface is also adapted to receive a second video signal from a source located outside of the residence (such as an incoming cable TV line). The interface transmits the second video signal onto the telephone link in yet another frequency range that is different from the first and second frequency ranges and from the voice signal frequencies. The second video signal is coupled via the telephone link for recovery by the receiver, which in turn applies it to the television.

Another general concept that this invention provides is the use of active telephone wiring (i.e., wiring that is also used for its normal purpose to carry telephone signals) as the transmission line leading from a main cable trunk (which is coaxial cable or fiber optics) to the individual subscribers. This significantly reduces the complexity and expense normally associated with cable TV wiring, above the reduction provided when the main cable trunk carries signals all the way to the subscriber. A major advantage of this wiring over coaxial cable is that nearly every residence (such as an individual house or an apartment unit in an apartment building) has one or more phone lines, each including at least one twisted pair (e.g., the red-green pair; typically, a second twisted pair of black-yellow wires is also provided) leading to it from

the telephone company trunk line. A second advantage is that signals applied to the telephone line are available at every telephone jack, rather than at a single coaxial outlet.

Thus, a general aspect of this invention is a system that provides video signal communication between a source of the video signal and a plurality of units that include destinations of the video signal and that includes an interface coupled to the source and to telephone lines, each of which serves at least one of the units and carries voice signals to and from one or more telephones coupled to the telephone line at said unit. The interface receives the video signal from the source, and transmits the received video signal onto at least one of the telephone lines in a selected frequency range that is different from frequencies at which the voice signals are carried on that telephone line. This causes the video signal to be coupled to a receiver which is connected to the telephone line at the unit served by that line and is adapted to recover the video signal from the telephone line and apply it to one or more of the destinations at the unit.

Preferred embodiments include the following features.

The source is a cable (e.g., electrical or fibre optic) that is linked to the interface and that carries a plurality of video signals. The destinations are, e.g., televisions. The units can be residences (such as individual houses or apartments in an apartment building) or offices in an office building. Hereinafter, the term "residence" will be used for all such units.

The interface is adapted to select one or more of the video signals in response to control information from a user or users of televisions at any residence and transmit the selected video signal or signals onto the telephone line that serves that residence for recovery and

application to one or more televisions in the residence. If multiple video signals are selected for a given residence, the interface transmit the video signals onto the telephone line that serves that residence at different frequencies within the selected frequency range. This prevents the selected video signals from interfering with each other.

The interface can select the same video signal for multiple residences and transmit the video signal onto the plurality of telephone lines that serve those residences. Further, the same video signal can be sent over the telephone lines at the same or different frequencies.

At least one of the residences includes an internal telephone link to which its receiver and at least one telephone is connected. The internal telephone link is connected to the telephone line that serves that residence, either directly or via a local interface. The local interface amplifies video signals received over the telephone line and couples them onto the internal telephone link. This helps compensate for attenuation that typically occurs during transmission to the local interface, thereby increasing the quality of the video signals recovered by the receiver.

At least one of the residences includes a source (e.g., a video camera) that applies a second video signal that applies said second video signal onto the internal telephone link in a second selected frequency range that is different from both the frequency range selected by the interface and the frequencies at which the voice signals are carried on the telephone link. The local interface amplifies the second video signal and couples it onto the telephone line that serves the residence to cause the second video signal to be coupled to the interface. The interface, in turn, transmits the second video signal to the source.

The interface is coupled between the telephone lines and corresponding public telephone lines (which carry voice signals at voiceband frequencies) that serve the residences. In one embodiment, the interface couples the voice signals between each public telephone line and each telephone line at voiceband frequencies, and the selected frequency range exceeds the voiceband frequencies.

In another embodiment, the interface converts the voice signals on the public telephone lines to a frequency range above voiceband frequencies before coupling the voice signals onto the telephone lines for transmission to the residences. In this case, at least a portion of the selected frequency range for the video signals includes voiceband frequencies. The local interfaces at the residences reconvert the voice signals to voiceband frequencies and change the frequency of the video signals to a frequency band above voiceband frequencies before coupling the voice signals and the video signals onto the internal telephone link.

A possible drawback of using active telephone wiring to transmit video signals (e.g., cable TV signals) to the residence according to this aspect of the invention is that the number of signals that can be effectively transmitted may be more limited. This, however, can be solved because only a very limited number of signals are typically useful at a single time. One recommended solution is to locate the channel selection device at the point of connection to the main telephone trunk (also called the "point of convergence" of telephone lines from multiple residences) and send only the selected video signals to each residence via the telephone line.

This arrangement can actually achieve extra economies if telephone lines from several subscribers converge at one point, as they do in apartment buildings and sometimes on telephone poles or pedestals. One economy

that can result is that the channel selection electronics for several subscribers can be embodied in a single device, thereby reducing hardware cost. The second economy is that scrambling of the signals is not necessary. Signals not paid for by a subscriber will simply not be handed off onto the telephone lines leading to the residence of that subscriber.

Ordinarily, piracy would be a problem because it is easier to "tap" an RF signal from a twisted pair, which is unshielded, than from a coaxial cable. Furthermore, a "tap" onto a twisted pair is less obvious than a tap onto a cable. Because the signals are "handed off" from a point of convergence, however, only specifically selected signals emerge from that point, and there will ordinarily be less than three video signals on any individual wire (as described in more detail below). By protecting that convergence point, therefore, fewer signals are available for piracy than in the case where coaxial cables reach all the way to the television. Because easy, surreptitious access to the convergence point will not be available when the point is on a utility pole or in the basement of an apartment building, piracy from the twisted pair distribution system of this invention is even more difficult.

The general principles and techniques described in U.S. Patent No. 5,010,399 include some of the ingredients useful to enable converging telephone lines to carry video and other signals from a point of convergence to the individual local networks (i.e. houses, apartment units, rooms in office buildings) in addition to carrying the telephone signals. Problems can arise, however, due to the unusually long path length of the wire branch leading between the point of convergence and the internal telephone network within a residence. Other problems can arise because the wire pairs from neighboring subscribers are

often tightly bundled near the point of convergence. This may cause a signal from one wire pair to be picked up by a neighboring pair in the bundle, causing interference. Finally, provision must be made for selection of cable TV channels from within each residence. One of the objects of this invention is to overcome these problems.

Using active telephone wiring as the transmission line for wideband signals (e.g., cable TV signals) leading from a main telephone trunk line to the individual subscribers can also improve upon communication systems other than those used to distribute ordinary cable TV. One example is the "video on demand" system described above. A shortcoming of the typical video on demand system is the coding and decoding (i.e., scrambling and unscrambling) that must be provided at each end of the transmission line. Another drawback is that the excess capacity on cable trunks carrying cable TV signals is typically very limited. If, for example, a cable TV franchise provides signals up to cable channel 63 (which extends between 462 Mhz and 468 Mhz), the "video-on-demand" signals are restricted to the frequencies above that. Using higher frequencies may be undesirable because the attenuation of the cable increases with increasing frequency, and most cable converters are not designed to extend that high. If the existing cable can transmit signals up to, for example, 600 Mhz, then only 132 Mhz, or the equivalent of twenty-two 6 Mhz AM channels, are available above channel 63 at each neighborhood. In this situation, at most 22 houses per neighborhood can receive video on demand.

Telephone wiring from a centralized location (such as the point of convergence discussed above) can be useful because it can replace the coaxial cable as the conductor leading from the cable trunk (e.g., the high-capacity fiber optic line) to the individual residences. One advantage of telephone wiring is that it provides a dedicated path from

the point of convergence to each subscriber. This means that signals on the optic fiber line that are "handed-off" onto an individual wire pair transmit to only one subscriber. This eliminates the need for scrambling which is otherwise necessary when many subscribers receive a signal (such as over a shared coaxial cable TV network) that only a limited group of them pay for.

A disadvantage, mentioned above, is that such a point of convergence at which conductors lead to a large number of subscribers is not always nearby. If some of the subscribers are a great distance from the convergence point, the attenuation of transmission may be too severe to allow reliable communication across the twisted pairs that comprise the telephone line.

This problem is less severe in the case of the residential units in an apartment building. Because these buildings typically consist of many units whose telephone wire pairs usually converge at a nearby point, such as when a "wiring closet" is provided for each floor, their telephone lines are particularly good candidates for providing this type of communication. Usually, there is a point in the basement of such buildings where the wiring from all units on all floors converges.

Commercial buildings also include locations where many telephone lines converge. Often, the individual wires leading to the various rooms of the building converge at what is called a "PBX," or private branch exchange. Such an exchange is provided because considerable communication between rooms is required that is not, of course, economically provided by the public telephone exchange.

As mentioned earlier, the popularity of teleconferencing has created a demand for video distribution within an office setting. Often, videoconferencing allows for a group of workers in a building to monitor a conference at a remote location.

This requires one-way communication of video. Other forms of video conferencing, however, require two-way video communication. Using telephone wires for these purposes is more complicated, of course, because at least two video signals must transmit in opposite directions. One solution, proposed herein, is to use more of the frequencies, or spectrum, available on each wire pair. Another is to use a different wire pair in the same bundle leading to each office, if it is available. Each of these causes special problems, as will be described herein. One of the objects of this invention is to overcome the problems associated with two-way communication of video across the telephone wires in an office building.

Because of the considerable communication demand between rooms in an office setting, a demand has also arisen for two-way video communication between rooms in the office. A difficulty in using the telephone wiring for transmission of video across that setting is that the conductive paths between the various offices are broken by the PBX. In U.S. Patent No. 5,010,399, a technique to provide a high frequency "bridge" between the various wires leading to a PBX was described, thus making the various wires appear, at high frequencies, as a single conductive path. In this application, that technique is expanded upon to provide switching of video between offices, and simultaneous communication of more signals.

In many office buildings, the telephone wiring is not the only network of twisted pair wiring that extends to each office and converges at a common point. Over the past several years, common communication networks that connect personal computers, known as Local Area Networks or LANs, have begun to use twisted pair wiring for their conductive paths. In the typical configuration, a digital electronic device serves as the "hub" for such a system, and a separate twisted pair wire connects from this center to

each of the computer nodes. Transmission of video across this medium involves the same problems encountered in transmitting across a PBX system. Additionally, extra difficulties are encountered because the signals that "naturally" transmit across the system, i.e. the digital computer signals, occupy a much wider band than telephone signals. In this application, the technique for communication across a PBX is expanded to provide the same capabilities for wiring networks that provide the conductive paths of a computer local area network (LAN).

In addition to video distribution to houses and apartment units and video communication within office buildings, there is a fourth communication system that can be improved upon by distributing video signals over multiple pairs of telephone wires. This system is the main public telephone network itself. The copper wires of this network are currently being replaced by fiber optics because these lines can carry much more information. Increasing the communication capacity to an individual residence using current technology requires installation of a fiber optic cable spanning the entire distance from the "local exchange" to the residence. The improvement described herein is the result of using the existing copper wires to communicate video and other signals over approximately the last 1000 feet of this link, i.e. from the main optical fiber trunks to electronic devices in subscriber facilities. This eliminates the need to install a new communication line between each residence and the main trunk. It also eliminates the need to adapt each electronic device in a residence to receive optical signals.

A new development in video communication colors the entire concept described so far. The new development is the advent of techniques that digitize and compress standard commercial video signals (such as NTSC or PAL) in

real time, without reducing information content, so that the resultant digital bitstream has a data rate that is slow enough to be expressed as an analog waveform in a remarkably narrow channel. This development presents the possibility that considerable programming will be transmitted in this form in the near future.

Accordingly, it is seen that the present invention provides a technique for one-way distribution of signals of a general nature that require bandwidths much wider than the 3 Khz voiceband currently in use. These signals are transmitted to multiple local networks of active telephone wiring, (i.e. the telephone wiring systems of several houses, apartment units, or rooms in an office building) from a signal source at a location where the active telephone wires leading to the residences converge. In the typical application this signal source will be a "tap" into high capacity communication link such as a fiber optic transmission line or a coaxial cable.

The interface provided by the invention includes a transceiver/switch located at the point of convergence. This device replaces the existing interface between the public telephone network (i.e., an ordinary telephone trunk line) and the telephone lines that lead to the individual residences. (These telephone lines are referred to below as "extended twisted pairs".) Typically, the existing interface will be a simple "punch-down" panel that provides electronic connections between the extended pairs and the pairs that are part of the trunk line. The transceiver/switch receives multiple signals (such as several channels of cable TV signals) from the high-capacity communication link such as a coaxial cable or fiber-optic line, and selectively switches these video signals onto the individual phone lines, together with the phone signals. Means are provided at each individual network (i.e. the internal telephone wiring of each

residence) to receive and separate these signals.

In addition, the invention allows each subscriber to control the signal selection by the transceiver/switch in situations in which a large group of signals on the high capacity communication link is made available for selection by any subscriber. Control (e.g. channel selection) is established by sending signals from a local network to the transceiver/switch over the extended twisted pair telephone lines, e.g., in the reverse direction from the direction of transmission of the selected video signals. A particularly appropriate application for such a system is as an alternative method of distributing cable TV service.

The invention also provides two-way communication of signals of a general nature with the high capacity transmission line. This allows the user to transmit wideband (e.g. 5 Mhz) signals of an arbitrary nature (such as video signals and high data rate computer signals) over the extended twisted pairs from the user's residence to the transceiver/switch, so that the transceiver/switch can add them to the high capacity transmission line for communication with, for example, a receiver at the point where signals transmitting in the "forward" direction originate (e.g., the video library discussed above.)

The invention further provides two-way switched video communication between the local networks (e.g. the rooms) in office buildings and in other buildings that have requirements for two-way communication.

Moreover, all of the communication capabilities discussed above can (and preferably do) use networks of twisted pair wiring that are also used for computer communications.

The communication techniques of the present invention can be adapted to provide the same capabilities when the signal source at the point of convergence provides video signals expressed as analog signals representing

compressed digital bitstreams.

It is important to note that this invention provides the video signal communication capabilities described above while preserving all of the features of the pre-existing telephone and computer communications. Thus, interference on the telephone lines between ordinary telephone communications and the selected video signals is avoided.

As discussed above, the interface includes a transceiver/switch that is connected to multiple pairs of telephone wiring and is interposed between telephone wire pairs from the local telephone exchange (the trunk line) and the extended telephone wire pairs leading to separate local networks of telephone wiring. The transceiver/switch also connects to a link used for long distance communication of many multiple signals, such as TV signals.

The invention also includes RF transmitters and RF receivers, described partly herein and partly in U.S. Patent No. 5,010,399, that are connected to the telephone wiring of the local networks and a local network interface device disposed between the local network wiring and the extended twisted pair wiring that leads to the transceiver/switch. These elements cooperate to provide the following results:

1) The transceiver/switch can select any one of the signals provided by the high-capacity communication link and transmit it along the extended wire pair leading to any one of the local networks. At least one video signal can be sent to every local network at one time.

2) Normal telephone communication on all local networks and between the local networks and the public network (trunk) is preserved. All pre-existing computer communication capabilities are also preserved.

3) A signal transmitted from the point of convergence will be received by the local network interface and retransmitted onto the local network, making it

available for reception by an RF receiver connected at any point on the local network. (In some embodiments, a local network interface is not included and signals transmitted at the point of convergence transmits directly onto the local network for reception by a video receiver connected thereto.)

4) Any RF transmitter connected to a local network can transmit a signal to the transceiver/switch by transmitting that signal onto the local network. A signal sent in this manner is received by the local network interface and retransmitted onto the extended twisted pair wire. (In some embodiments, a local network interface is not included and a signal applied to a local network by an RF transmitter is transmitted directly to the transceiver/switch without interception and retransmission.) At least one video signal from each local network can be transmitted in this direction at the same time.

5) Any RF video receiver on a local network can detect control signals from infrared transmitters (e.g., hand-held remote control devices typically used to control the operation of televisions, VCRs, etc.) and transmit them to the transceiver/switch, allowing the user to control program selection at the transceiver/switch from the location of, e.g., any television connected to the local network through an RF receiver.

6) In addition to selecting any one of the signals provided by the high-capacity communication link for transmission along the extended wire pair leading to any one of the local networks, the transceiver/switch can also select any of the video signals received from one local network for transmission to any other local network.

Other features and advantages of the invention will become apparent from the following detailed description, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 1A show a signal splitter according to the invention that is useful with the communications systems described herein and, e.g., also in the communications systems described in U.S. Patent No. 5,010,399.

Figure 2 illustrates certain properties of transmission of RF signals.

Figure 3 is a block diagram of an automatic gain control (AGC) technique according to the invention.

Figure 4A is a block diagram of a transmitter/receiver pair according to one embodiment of the invention for communicating high-fidelity audio signals over active telephone wiring using FM techniques.

Figure 4B shows a component of the receiver of Fig. 4A in more detail.

Figure 5 is a block diagram of a transmitter/receiver pair according to another embodiment of the invention for communicating high-data rate digital signals over active telephone wiring.

Figure 6 is a block diagram of a transmitter/receiver pair according to still another embodiment of the invention that uses digital techniques to communicate high-fidelity audio signals over active telephone wiring.

Figure 7 is a block diagram of a pair of transceivers according to yet another embodiment of the invention for communicating video, hi-fi, and control signals over active telephone lines.

Figure 8 shows a portion of the coupling network used in the transceiver pair of Figure 7.

Figure 9 shows another portion of a coupling network used in the transceiver pair of Figure 7 that provides directional multiplexing.

Figure 10 is not used in this application.

Figure 11 is a block diagram that shows an interface between an active, internal residential telephone network and a public telephone network according to this invention, and several video transmitters and video receivers connected to the internal telephone network.

Figure 12 shows an RF/video processor within the interface of Fig. 11 in more detail.

Figure 13 is a block diagram of a video receiver used in the system of Fig. 11 (and is identical to Figure 2 of U.S. Patent No. 5,010,399.)

Figure 14A shows how the RF spectrum below 140 Mhz may be allocated for transmission of video signals across the internal telephone network of Fig. 11.

Figure 14B illustrates an alternate allocation of a portion of the RF spectrum of Fig. 14A.

Figures 15A-15C depict three embodiments of an RF converter in the video receiver of Fig. 13.

Figure 16 shows a control signal processor in the RF/video processor of Fig. 12 in more detail.

Figure 16a shows a component of the control signal processor of Fig. 16 in more detail.

Figure 17 shows a low-frequency processor in the interface of Fig. 11 in more detail.

Figure 18 shows an embodiment of the master controller in the interface of Fig. 11 in more detail.

Figure 19 shows an alternative embodiment of a portion of the RF/video processor of Fig. 12.

Figure 20 is not used in this application.

Figure 21a is a block diagram showing the placement of the transceiver/switch and local network interfaces in a system of telephone lines leading to multiple local networks according to one aspect of to the invention.

Figure 21b is a block diagram showing the placement of the transceiver/switch of Fig. 21a between a PBX ("private branch exchange") and the system of telephone

lines leading to different rooms in an office building according to another aspect of the invention.

Figure 22 is a functional block diagram of the transceiver/switch of Figs. 21a and 21b.

Figures 23a-23c show different spectral distributions of video signals that are useful in understanding the invention.

Figure 24 is a block diagram of a processor in the transceiver/switch of Fig. 22.

Figure 24a shows additional details of a component of the processor of Fig. 24 that serves as an interface to the high capacity communication line.

Figure 25a shows another component of the processor of Fig. 24 that performs the distribution of signals to the various local networks.

Figure 25b shows an alternative embodiment of the component of Fig. 25a that allows transmission of signals from one local network to a different local network.

Figure 25c shows another alternative embodiment of the component shown in Fig. 25a.

Figure 26a shows additional details of still another component of the processor of Fig. 24 that performs the reception and disposition of signals sent from the various local networks.

Figure 26b shows an alternative embodiment of the component of Fig. 26a.

Figure 27 is a block diagram of a control signal processor in the transceiver/switch of Fig. 22 for processing the signals sent from the local networks to control signal selection and other processing at the point of convergence.

Figure 28 is a table that summarizes the signals transmitted across the extended pairs in one of the examples used in the disclosure.

Figures 29a and 29b are block diagrams of

embodiments of a signal separator in the transceiver/switch of Fig. 22, showing the electronics that route signals onto multiple extended pairs, route signals received from each extended pair, and process the telephone signals on the extended pairs.

Figure 30 illustrates one embodiment of a local network interface of Fig. 21a.

Figures 31a-31c show additional details of various embodiments of components of the local network interface of Figure 30 that process the non-telephone signals transmitting between the local networks and the transceiver/switch.

Figure 32 shows one of the RF processors that performs part of the function of the local network interface of Fig. 30.

Figures 33a and 33b show additional details of the components of the local network interface of Fig. 30 that processes the telephone signals transmitting between the local networks and the transceiver/switch.

Figure 34 shows additional details of a wiring closet booster that includes several local network interfaces for boosting the levels of signals transmitting in both directions between the transceiver/switch and several of the local networks.

Figure 35 is a block diagram of a digital video receiver useful with the systems of Figs. 21a and 21b.

Figure 36 shows another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Part I - RF Broadcast System Utilizing Internal Telephone Lines

The devices described herein, and those described in U.S. Patent No. 5,010,399, feed RF signals onto active telephone links (i.e., telephone wiring that is in use for transmission of ordinary voiceband signals) and recover signals from the telephone wiring. The devices will also function correctly when used over inactive telephone links.

Communication of video and infrared control signals in this manner was first described in U.S Patent No. 5,010,399. This document describes methods by which hi-fi audio and digital signals are communicated across active telephone wiring as well.

When signals are transmitted over a telephone network, such as the internal telephone wiring of a residence, the signals spread to all parts of the network, and are thus available for recovery by any device that is connected to the telephone wiring. As such, these devices use the wiring as a broadcast medium. They use RF frequencies, and function like wireless communication devices, except that telephone wiring, rather than the airwaves, is the medium.

The devices of this invention are designed to work on any network of telephone wiring in which an uninterrupted two wire conductive path (e.g., the red-green pair in a four conductor cable typically used to carry telephone voice signals) exists between any two points on the network. The telephone wiring need not be "point-to-point" (i.e., splits and other junctions in the telephone wiring may exist between the two points) and loops are allowed. The internal network of telephone wires of nearly all residences fit this description. The only common exceptions are residences where all jacks are directly connected to a central electronic switch/processor, sometimes referred to as a KSU or key-service unit. U.S. Patent No. 5,010,399 (in connection with Fig. 5) describes an adapter that provides an RF bypass around such a switch, allowing transmission of video and control signals to all points of the telephone wiring. The same adapter can be used to allow other RF signals, including the signals described herein, to bypass the switch and broadcast across the telephone network. Such an adapter can also be used to repair breaks in the conductive paths of other types of telephone wiring networks.

U.S. Patent No. 5,010,399 describes a pair of transceivers which exchanges video and infrared signals over the active telephone wiring. The first transceiver transmits video signals to and receives infrared control signals from the second transceiver, and, of course, the second transceiver does the opposite. The first transceiver is referred to therein as the "video source transceiver" because it connected to a video source (such as a VCR). The second transceiver is called the "television transceiver" because it ordinarily is connected to a television.

In this document, devices that transmit video signals over an active telephone network are referred to as "video transmitters," even though they may send or receive signals of other types (such as purely audio signals, digital signals, etc.). Devices that receive video signals from active telephone wiring are denoted as "video receivers". Devices that both transmit video signals to and receive video signals from a telephone network are referred to as "video transceivers"

Increasing the No. of Channels and the Distance Over Which RF Signals Can Transmit on Telephone Wiring

Using the techniques disclosed in U.S. Patent No. 5,010,399, a full cable band spanning sixty video channels can be fed to a one foot length of telephone wiring and transmitted with high quality without violating any FCC regulations. As the distance between transmitter and receiver increases, however, factors come into play which cause higher frequency signals to drop out. The same phenomenon occurs with RF signals of other types. Thus, transmission length and the total number of available channels are closely related quantities. In this section, several techniques are disclosed to extend the limits to these quantities.

The following equation governs whether transmission of an RF signal across telephone wiring can succeed:

$$SL - TL - PA > SNR + IL \qquad \text{(equation \#1)}$$

where,

SL = Source level (dBmV),

TL = Transmission loss (dB),

PA = Point attenuation (dB),

SNR = Signal to noise ratio (dB), and

IL = Interference level (dBmV).

That is, high-quality video signals will be received if source signal level, less transmission loss, less point attenuation, exceeds the minimum required SNR by the amount of the interference. Each of these components is now discussed in the context of transmission across telephone wiring.

1) Signal level (SL). Generally, the technology required to amplify a video signal to the levels of interest in the systems disclosed in this application is simple and inexpensive. The real limits to signal level are dictated by legal (e.g., FCC) restrictions on the signal energy radiated from the wire. In experiments described in U.S. Patent No. 5,010,399, NTSC signals with a picture carrier at 61.25 Mhz applied to four conductor telephone wiring at 40dBmV slightly exceeded U.S. FCC regulations. Radiation caused by a signal at a fixed energy level increases as the frequency of that signal increases.

2) Transmission loss (TL). This is the signal energy lost by transmission across the wiring. This quantity is linearly related to the length of the wiring and increases significantly as frequency increases. At 100 Mhz, for example, typical telephone wiring attenuates energy at approximately 15dB per 100 feet, while at 175 MHz, attenuation is approximately 30dB per 100 feet.

3) Point Attenuation (PA). This quantity refers to the signal energy lost at a single point on the conductive path. Examples are the attenuation of RF energy by telephones, by "open" telephone wall jacks (i.e., jacks which are not connected to a telephone), and the loss at splits in the wiring. The loss at a split is approximately 3.5 dB. The loss at an open jack is smaller (less than 3.5 dB) because most of the energy is reflected back onto the line. Telephones can have a much higher attenuation affect than either an open jack or a split.

4) SNR. This is the minimum SNR required at the receiver input to generate a good picture and is largely a function of how the signal is encoded and how picture quality is measured.

5) Interference level (IL). This is the energy level of the interfering signals found on the wiring. Some examples are signals from citizens' band (CB) radios and amateur radio signals that might be picked up by the wiring acting like an antenna. (The ability of the wiring to act as an receiving antenna increases with frequency, as does the radiating ability of the wiring.) Another interference source is the non-linear effects of certain telephones on RF signals. This is described in the section that immediately follows. Still another source of interference is the energy that crosses over from a second RF signal at the same frequency on a second pair of telephone wires in the same wire bundle. (As is known, a typical residential telephone wire bundle or cable includes two pairs of wires: a red-green pair, which is normally used for the primary line in residential telephone hook-ups, and a black-yellow pair, typically unused unless the residence is equipped with a second telephone line. In structures other than residences, large bundles are used that consist of many pairs of telephone wires.) This phenomenon is known as crosstalk and increases with increasing frequency.

It is interesting to note that transmission loss, radiation, interference, and crosstalk all increase with frequency, making the use of lower frequencies to transmit video, audio, or digital signals over the telephone lines according to the invention much more attractive.

To summarize some of the transmission properties discussed above, it is seen that increasing SL, decreasing TL, decreasing PA, decreasing minimum SNR, and decreasing IL will allow an RF signal at a fixed energy level to transmit over longer distances on a given network of wiring. Equivalently, given a fixed transmission path and a fixed signal energy, those changes to SL, TL, PA, IL, and minimum SNR allow video to transmit at higher frequencies. In the following five sections, methods to improve transmission via changes in PA, minimum SNR, and IL are disclosed.

Decreasing Attenuation by Connected Telephone Devices (Figs. 1, 1A)

Many telephone devices load down RF energy on the telephone line. This attenuation can occur in both the on-hook and off-hook conditions. As described in U.S. Patent No. 5,010,399, when connected to a telephone network across which RF signals are transmitted, telephone devices can drain RF signal energy, lowering the level of the RF signal at the receiver. Given the attenuation properties of a specific telephone device, the degree of reduction of the RF energy level at the receiver depends upon the location at which the telephone device is connected to the telephone network.

When applied by a source (e.g., the video source transceiver) to the telephone wiring using the techniques described in U.S. Patent No. 5,010,399, RF energy is transmitted between the source and receiver (e.g., the television transceiver) over one or more conductive paths, that is, one or more branches of the telephone wiring. The shortest path is usually dominant, i.e., more energy arrives at the receiver by traversing the shortest path than by traversing any other. This is because energy attenuation is directly related to path length. One situation where the shortest path does not dominate is when it includes many junctions (such as branches that connect to secondary jacks), or splits. In this case, a longer path may be the dominant path. Another exception is where many telephone devices connect to the shortest path, attenuating the energy level below that of another path.

According to theory, there is a rough inverse relationship between the amount of RF energy drained by a telephone device and the distance of that device from the dominant transmission path. As described in U.S. Patent No. 5,010,399, physically long branches will serve to reduce the attenuation effect of a connected telephone device. The attenuation introduced by telephone devices connected through relatively long branches will be limited

by the 3.5 dB splitting loss that long branches impose at a junction. If, on the other hand, the telephone device is connected to the dominant path through a branch that is not long enough to impose significant attenuation (e.g. less than 1 dB), the effective reduction of energy from the path can approach the full dissipative effect of the telephone device.

As mentioned in U.S. Patent No. 5,010,399, if a telephone device is connected to the dominant path through a low-pass filter, it cannot significantly drain RF energy from that path. It is suggested therein that low pass filters be supplied with both the transmitter and receiver so that telephone devices sharing the same telephone jacks as the transmitter and receiver do not load down the video signals. Because they necessarily connect to the dominant path, these devices are considered to be the most likely to cause signal attenuation.

Referring to Figs. 1 and 1A, experiments conducted by the inventors have since indicated that in many residences, providing all telephones with low pass filters decreases attenuation sufficiently to significantly increase the number of channels over which transmission can succeed. Such a procedure is feasible because simple, inexpensive low-pass filters can be enclosed in a compact housing which serves as a splitter 161 and includes standard RJ-11 telephone connectors 166, 167, 168 for providing connections to the telephone network, the telephone devices, and the video transmitter or receiver.

Splitter 161 includes a network port 168 that includes a male RJ-11 plug which is simply inserted into an existing RJ-11 outlet of the telephone network (not shown), replacing the single outlet with two alternative outlets, both of which are female RJ-11 connectors. One of the alternative outlets is a phone port 166 to which a telephone plug is connected. Within splitter 161, phone

port 166 is connected to network port 168 through a pair of low-pass filters 162a, 162b. Low pass filter 162a filters signals present on the red-green wire pair, and signals on the black-yellow pair are applied to filter 162b.

Devices that transmit and receive RF signals are connected to splitter 161 at RF port 167. These devices include, of course, the video transmitters and receivers described in U.S. Patent No. 5,010,399, as well as any of the transmitters and receivers described herein. The black-yellow wire pair is directly connected between RF port 167 and network port 168. A high-pass filter 164, double-pole-double-throw switch 165, and terminator 163 are connected as shown to the red-green pair between RF port 167 and network port 168 for purposes described in detail in the following section.

Low pass filters 162a, 162b also suppress the transients from telephone switch-hook signals. These transients can include significant energy at higher frequencies. To suppress substantially all transients, however, an additional low-pass filter should be placed along the path that connects the telephone wiring of the residence to the public telephone network. In a typical residence, this means placing the low-pass filter at the point where the telephone company wire enters the residence. This will suppress substantially all high frequency energy that originates at the public exchange.

Although it is unlikely that the public exchange will provide significant high frequency energy, this filter also serves the purpose of blocking the high frequency energy transmitting on the residential wiring from creating a violation of governmental regulations by conducting onto the public telephone system. For example, Part 68 of the U.S. FCC regulations places severe limits on the amount of energy that can conduct onto the public networks below 6 Mhz.

Reducing the Likelihood of Interference from Multipath Transmissions (Figs. 1, 1A, 2)

U.S. Patent No. 5,010,399 describes a series of tests involving transmission of television video signals across wiring of an internal residential telephone network to a television for viewing. One purpose of the tests was to determine if a type of interference called "ghosting" or "multipath" would appear in the image displayed on the television screen.

Multipath interference is caused by reception of the video signal of similar energy levels from multiple transmission paths. The classic example of multipath interference with video is when a signal transmits from an antenna to a television via two different paths. The dominant path is the one that extends directly from the antenna to the TV. The secondary path reflects off a nearby building before arriving at the television.

The possibility of multipath interference with signals transmitting over telephone networks is present because of the many paths that signals can follow between source and receiver. This interference, however, was not observed in any of the tests performed. A brief explanation of its absence was included in U.S. Patent No. 5,010,399. In the following paragraphs, the issue of multipath interference is discussed in greater detail, and a technique to eliminate it in situations where it may occur is described.

As mentioned above, multipath interference can occur when a video signal is transmitted between the video signal source and receiver over paths of different lengths. The signal whose energy at the receiver is highest has usually traversed the most direct path. If a reflected signal is received at a level comparable to the signal provided by the direct path, multipath interference is created in the form of a duplicated image that is offset horizontally on the television screen vis-a-vis the first. An example of multipath interference in the case of transmission over

airwaves is where a second path reflects off of a nearby building before reaching the receiver.

Referring to Fig. 2, reflections can also take place on a network of telephone wiring. The most common points of reflection are where the wiring splits, and where a branch of wiring terminates at an open jack. Both of these types of reflections are shown in Fig. 2, which illustrates a portion of a telephone wiring network that includes a video transmitter 195 that transmits a video signal across branches 195a, 195b of the wiring to a video receiver 196. Branch 195c joins branches 195a, 195b at split 199. If branch 195c is short relative to one quarter of the wavelength of the signal (e.g. less than 10 meters at 30 Mhz) and is not connected to any telephone devices, theory dictates that its effect on the signal transmitting to receiver 196 will be minimal. (If branch 195c is short and is terminated with a telephone device, attenuation occurs as described above.) If the length of branch 195c is comparable to or larger than a quarter of a wavelength, however, a portion of the video signal will be reflected, at split 199, back to transmitter 195 with a 5 dB loss; the remainder of the video signal will be divided between branch 195b (leading to receiver 196) and branch 195c (which connects to termination 197). The signal level on each path 195b, 195c will be 3.5 dB below the level of the video signal incident at split 199 from transmitter 195.

If termination 197 is simply an open telephone jack, theory dictates that termination 197 will induce a phase shift and a small energy loss in the video signal on branch 195c which will then be reflected back towards split 199. At split 199, part of the energy in the reflected signal will again be reflected, this time back to termination 197, with a 5dB loss, part will be transmitted to transmitter 195 with a 3.5 dB loss, and part will be transmitted towards receiver 196, also with a 3.5 dB loss. This last component, the energy transmitting towards receiver 196,

will represent the reflection with the highest level. It will have twice suffered a 3.5 dB loss at split 199, a reflection loss (induced by termination 197), and also the extra attenuation of traversing branch 195c two times. The original video signal from source 195, on the other hand, will have suffered only a single 3.5 dB loss at split 199.

The amount of offset between the video signal that reaches receiver 196 through reflections in branch 195c and the video signal that is applied to receiver 196 directly from source 195 (i.e. through branch 195a, split 199, and branch 195b) is related to the time delay between reception of the direct and the reflected signal. The following analysis of television dynamics reveals how much delay is necessary to create visible interference.

The horizontal sweep rate of an NTSC television is 15,750 scans, or lines per second. If there are 300 pixels of resolution per line, 2.1×10^{-7} seconds elapse for each pixel. At a transmission speed of 3×10^{8} meters per second, this means that the reflected path must be approximately 120 meters longer than the direct path to cause a two pixel offset. Transmission speed over telephone wiring will be somewhat less, perhaps around 2×10^{8} meters per second, meaning that a direct-to-reflected path length differential of approximately 80 meters will cause a two pixel offset.

For the reflected signal to cause interference, it must be delayed long enough to cause significant offset while retaining enough of its energy to have a visible effect on the television picture. If two pixels are considered to be the minimum noticeable offset, then the above computations indicate that the delay caused by a 80 meter or 250 feet detour will cause a two pixel offset. This can be caused by a branch 125 feet long.

At 30 MHz, attenuation of telephone wiring is approximately 7 dB per one hundred feet. At that rate, the reflected path will suffer a 17.5 dB loss over a 250 foot